Vol. 8, No. 5 September-October, 1946

THE OSCILLOGRAPHER

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THE CATHODE-RAY OSCILLOGRAPH AS A SIGNAL GENERATOR

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The March-April, 1946, and part of the May-June, 1946, issues of the Oscillographer were devoted to the subject of making signal connections directly to the deflection-plate terminals of a cathode-ray oscillograph, and to a method for observing two signals simultaneously without the use of an electronic switch. This issue deals with a further extension of the subject, using the cathode-ray oscillograph as a signal generator. Signals will be taken off the deflection-plate terminals instead of being fed in. Throughout this article, the Du Mont Type 208-B Cathode-ray Oscillograph will be used as a typical example, and diagrams showing connections to the deflection-plate terminals will apply to this instrument.

The Cathode-ray Oscillograph as a Pulse Generator

Any cathode-ray oscillograph incorporating a push-pull sweep amplifier is capable of being used as a generator of either positive or negative pulses of relatively short duration at repetition rates limited only by the sweep-frequency range of the instrument. Some of the simpler types of oscillographs having single-ended amplifiers are capable of producing only positive or negative pulses depending on their design.

Figure 1 indicates the connections required to use the oscillograph as a pulse generator. The values of C_1 and R_1 are so chosen that their time constant RC is extremely short (approximately 5%) compared to the period of one sweep cycle. Under the conditions that this time constant is short compared to the time required for one sweep cycle, the sawtooth voltage present at deflection plate D_2 will be differentiated as shown in Figure 2.

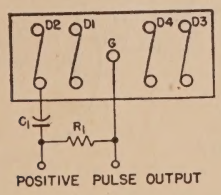

FIGURE 1—Method of Obtaining Positive Pulses from the Sweep Amplifiers of the Type 208-B Cathode-ray Oscillograph.

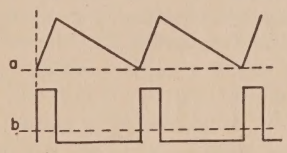

FIGURE 2—a. Sawtooth Voltage at Deflection Plate D_2. b. Positive-Pulse Output Across R_1 of Figure 1.

If it is desired to obtain negative pulses instead of positive pulses, as shown in Figure 2, the connection should be made to deflection plate D_1 rather than to D_2.

A pulse signal, such as provided by this method, is useful as a source of synchronizing signal for equipment requiring an initiating trigger. For example, an Eccles-Jordan trigger circuit, or a "dog-leg" multivibrator can be triggered by these pulses and its output easily studied with the cathode-ray oscillograph, since the time base

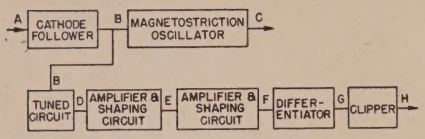

FIGURE 3—Block Diagram of Circuit Required for Measuring Speed of Sound Through Solids or Liquids.

of the instrument will always be automatically synchronized with the action of the device, regardless of the setting of the sweep-frequency controls of the oscillograph.

More-Complex Circuits Using the Differentiated Sawtooth Wave

In the following example, a more-complex problem will be analyzed and a method for solution suggested involving circuits dependent for their action on the differentiated sawtooth pulse: Suppose it is desired to measure the thickness of some material such as concrete by the pulse-reflection method. The differentiated pulse obtained as in Figures 1 and 2 is first fed through a cathode-follower stage in order to obtain a pulse source of low impedance, and it then is used to key two oscillators. One oscillator is of the magnetostriction type tuned to a supersonic frequency, and the other oscillator is essentially a shock-excited, tuned circuit whose output will eventually be used for timing purposes. Figure 3 shows the block diagram of the required circuit, and Figure 4 the oscillograms of signals obtained at various points. The damping on the tuned circuit of Figure 3 is adjusted so that the wave-form shown in Figure 4d is reduced to zero just before the end of one sweep cycle and the beginning of the next one.

Recalling that the pulse shown in Figures 4a and 4b occurs during the return-trace time of the oscillograph, it will be noted that the trailing edge of the train of supersonic waves (Figure 4c) is coincident with the start of the forward sweep of the oscillograph time base. The magnetostriction oscillator is coupled electro-mechanically to the concrete under test. The pulse output,

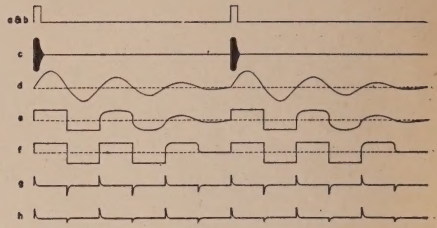

FIGURE 4—Waveforms Obtained at Various Points on the Block Diagram Shown in Figure 3.

as shown in Figure 4h, is applied to one of the vertical deflection plates and will serve as timing markers. The reflected pulse is picked up either by a magnetic or crystal type of vibration pick-up whose output is connected to the Y-axis amplifier of the cathode-ray oscillograph. If the attenuation in the test specimen is high, the Y-axis gain control of the oscillograph will have to be advanced toward maximum in order to provide sufficient amplitude of the reflected pulse. This may cause the transmitted pulse to overload and block the amplifier, and would therefore require some type of amplitude limiting or clipping stage between the pickup and the oscillograph.

Connections to the rear-terminal panel of the Type 208-B for the problem described above are shown in Figure 5a, and the indication on the cathode-ray screen in Figure 5b.

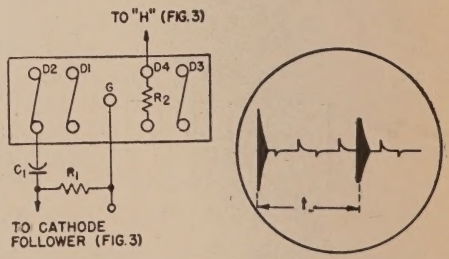

FIGURE 5—a. Connections Required for Operating Circuit of Figure 3. b. Typical Presentation of reflected pulse on the screen of the cathode-ray tube. At the left is seen the trailing edge of the supersonic pulse. Between the second and third time markers, the reflected pulse is indicated. The elapsed time is "t."

This method and circuit may also be used to measure the speed of sound through various solid or liquid substances. An identical test setup would be used, but the crystal or magnetic

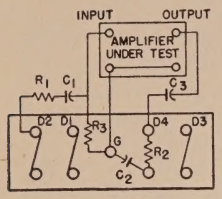

FIGURE 6—Connections Required to Make Linearity and Frequency-Response Measurements on an Audio Amplifier.

pick-up would be placed at a measured distance from the point at which the supersonic pulse is initiated.

Since the return-trace time of the saw-tooth-sweep signal is a relatively fixed percentage of the forward-trace time, the duration of the supersonic pulse will be a function of the sweep frequency selected. Where the sample is relatively thin, and therefore the elapsed time short, the sweep frequency selected must be high in order to measure elapsed time with any degree of precision. This will automatically make the pulse duration short, so that no interference between the trailing edge of the transmitted pulse and the reflected signal will result.

The Use of the Sweep Voltage for Testing Amplifier Linearity and Frequency Response

The commonly accepted method for checking a class A amplifier for amplitude distortion is to use a milliam-

FIGURE 7—Presentation of Test Result from Figure 6 on the Cathode-ray Screen. a. X-axis-amplifier Gain Control Low—No Linear Distortion. b. X-axis-amplifier Gain Control Advanced—No Linear Distortion. c. X-axis-amplifier Gain Control Advanced Further—When pattern departs from a straight line, it indicates that the amplifier under test is being overloaded.

meter in the plate circuit, and apply a sine-wave signal at the grid. If the amplifier is linear, the milliammeter will show no change as the amplitude of the signal at the grid is varied from zero to maximum. The assumption that is made in this case is that the applied signal does not vary from a pure sine wave as its amplitude is changed. This is not always true, un-

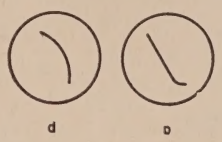

FIGURE 8—a. Low-Frequency Distortion on Test Amplifier. b. High-Frequency Distortion on Test Amplifier.

less a high-quality signal generator is used. It should also be pointed out that this method checks only for amplitude distortion, and not for phase distortion.

It is also common practice to use a square wave for checking both the transient and phase response of amplifiers, but this method is not too satisfactory in checking amplitude distortion. Furthermore, both of the above methods require the use of auxiliary test instruments such as square-wave and sine-wave generators, milliammeters, and possibly harmonic analysers.

The sweep voltage from a cathode-ray oscillograph may be used to good advantage to check amplitude, phase, and frequency distortion without any additional equipment aside from a rather simple attenuator. This method will not indicate the absolute percentage of distortion present, but it does serve as a quick check to determine the presence or absence of distortion, and to determine the maximum signal amplitude that can be handled by the amplifier without overloading it.

For this test, the connections indicated in Figure 6 are applicable. C_1, C_2 and C_3 are all of an adequate size to pass the sawtooth signal without appreciable attenuation or distortion. If the voltage gain of the amplifier under test equals "A" then the values of R_1

and R_3 should be chosen so as to satisfy the following approximate conditions:

$$\frac{R_3}{R_1 + R_3} \cong \frac{2}{A} \qquad (1)\ *$$

$$R_1 + R_3 > 2 \text{ meg.} \qquad (2)\ **$$

Equation (1) simply states that the output of the amplifier will be approximately equal to the amplitude of the sawtooth signal on the horizontal deflecting plates of the oscillograph, and the conditions of equation (2) are necessary so that the horizontal amplifier of the oscillograph will not be loaded excessively. When the above two equations are applied, the pattern seen on the screen of the cathode-ray tube will be a straight line at approximately either 45° or 135°, depending on the number of stages in the test amplifier.

After the connections as indicated in Figure 6 are made, the gain control of the X-axis amplifier on the cathode-ray oscillograph should be turned down to zero, and then slowly advanced while observing the results on the cathode-ray screen. Figures 7a, b, and c, illustrate the variations of the trace as the gain control is advanced.

This method can also be used as a quick and relatively simple determination of the band width of the amplifier. To make this test, the gain control of the X-axis amplifier is set at a nominal value to insure that the test amplifier is operating in its linear range. The indication on the screen should be similar to Figure 7b. The coarse-frequency and fine-frequency controls are then varied until the presentation on the screen starts to depart from a straight line. Figure 8a indicates the oscillogram obtained when the sweep frequency is reduced toward the minimum point, and the test amplifier does not have sufficiently good low-frequency response. Figure 8b indicates the oscillogram that will be obtained when the sweep-frequency control is advanced toward its maximum range, and the high-frequency response of the test amplifier is not adequate to pass the signal without distortion. Again it should be pointed out that this method is only a quick, qualitative check which would indicate the flat portion of the frequency characteristic of the test amplifier, and the departure from a straight line at either the low or high frequency indicates that frequency distortion is present, but one cannot easily determine the magnitude of such distortion.

*For oscillographs with balanced amplifiers. Use 1/A for oscillographs with unbalanced deflection amplifiers.

**If the input capacitance of the test amplifier is high, a frequency-compensated attenuator may have to be substituted. Refer to the March-April, 1946, issue of the "Oscillographer" for information on this subject. Also, if the input resistance of the test amplifier is low compared to R_3, the value of R_3 in both equations must be changed to allow for the shunt resistance added by the amplifier.

Conclusion

The three examples given in this article are meant to be descriptive, and not by any means restrictive. There are many uses to which the sweep voltages generated by a cathode-ray oscillograph may be applied. The only requirements are an active imagination, and some basic knowledge of circuit behavior.

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